

PATENT COOPERATION TREATY

PCT

07 NOV 2001

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P60049WO	FOR FURTHER ACTION		See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No PCT/GB00/02736	International filing date (day month year) 17/07/2000	Priority date (day month year) 19/07/1999	
International Patent Classification (IPC) or national classification and IPC G02B27/22			
Applicant [THE SECRETARY OF STATE FOR DEFENCE] QINETIQ LIMITED			

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.



2. This REPORT consists of a total of 5 sheets, including this cover sheet.

☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 12 sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☒ Certain observations on the international application

Date of submission of the demand 15 02 2001	Date of completion of this report 07 11 2001
Name and mailing address of the international preliminary examining authority  European Patent Office - P.O. Box 5518 Patentamt 2 Nu-2000 HY R SW K - P.O. Box Tel: +41 71 341 3341 Fax: +41 71 341 3341 Fax: +41 71 341 3341	Authorized officer Ward, S 

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/02736

I. Basis of the report

1. With regard to the **elements** of the international application (*Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17):*)

Description, pages:

7-10,12-15	as originally filed			
1-6,6a,11	as received on	12/06/2001	with letter of	08/06/2001

Claims, No.:

1-14	as received on	12/06/2001	with letter of	08/06/2001
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Drawings, sheets:

1/6,3 6-6/6	as originally filed			
2/6	as received on	12/06/2001	with letter of	08/06/2001

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT**

International application No. PCT/GB00/02736

4. The amendments have resulted in the cancellation of:

- ☐ the description. pages:
- ☐ the claims. Nos.:
- ☐ the drawings. sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-14
	No:	Claims	
inventive step (IS)	Yes:	Claims	1-14
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-14
	No:	Claims	

2. Citations and explanations
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT - SEPARATE SHEET**

International application No. PCT/GB00/02736

1. Reference is made to the following documents:

D1: WO9843441 A

**D3: MODERN OPTICAL ENGINEERING, Warren J Smith, McGraw-Hill 1966,
pages 124-128**

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or i

- 2.1 The subject-matter of claim 1 satisfies the requirements of Articles 33(2) and 33(3) PCT. The document D1 is regarded as being the closest prior art, and discloses (see page 6, lines 11-19 and figure 2): A compound lens (for example (40,1)) for use in an array of such lenses (40,1;40,2;40,3) comprising at least two lens elements (41,1 - 49,1), including a front lens element (49,1) having a front lens surface which is the largest diameter lens surface. The subject-matter of claim 1 differs from the closest prior art in that the exit pupil of the compound lens is bounded by and lies in the plane of the edge of the front lens surface, whereas in the document D1 (see page 6, lines 15-17 and figure 2), the exit pupil of the compound lens (40,1) is "defined by the front projection lens" (49,1), the precise plane of the exit pupil not being explicitly given.
- 2.2 The problem to be solved by claim 1 is the elimination of dark spaces between images in the "viewer space" of an autostereoscopic projection system. The skilled person would derive from document D1 (see page 3, lines 12-14) that these dark spaces can be eliminated if the lenses have adjacent abutting exit pupils, however, D1 acknowledges (page 10, lines 1-2) that there are "practical constraints in making the exit pupils of the lens systems abut without any gap". D1 then goes on to describe a method of compensating for the non-abutment of the exit pupils. In contrast, the above-mentioned difference between claim 1 of the present application and D1 results in a lens having an exit pupil so arranged that an array of such lenses can have their exit pupils directly abutting. This difference is not disclosed or suggested by D1 or any of the other available prior art, and consequently satisfies the requirements of Articles 33(2) and 33(3) PCT.
3. Claim 11 describes a method of designing a compound lens which would appear to inevitably result in a design corresponding to the new and non-obvious lens of claim 1, hence claim 11 satisfies the requirements of Articles 33(2) and 33(3) PCT.

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT - SEPARATE SHEET**

International application No. PCT/GB00/02736

4. All other claims depend on claims 1 or 11, and therefore satisfy the requirements of Articles 33(2) and 33(3) PCT.

Re Item VIII

Certain observations on the international application

5. The term "aperture stop" as used throughout the description and claims has been interpreted according to the definition given in the description on page 6, lines 16-17. It is pointed out that this definition is not the conventional definition of the term (see e.g. D3, page 124) contrary to Article 6 PCT. The definition given in the description appears to be identifiable with an "effective aperture stop" as described, for example, on page 126 of D3.

REPLACED BY
ART 34 AMDT.

Compound Lens Arrangement for use in Lens Arrays

- 5 The present invention relates to a compound lens arrangement for use in arrays of lenses and in particular to a compound lens arrangement for use in arrays of lenses or for use in projectors arranged in an array in multi-perspective autostereo projection systems.
- 10 In known multi-perspective autostereo projection systems the images from a plurality of projectors which show different perspective views of an object are projected onto a direction selective projection screen, such as a field lens. Such screens have the characteristic of re-forming the array of images of the projector lens exit pupils in a "viewer space" so
- 15 that each viewer of the screen sees a stereo image pair and accordingly sees a three dimensional image. Thus, if a viewer horizontally crosses between adjacent images, the three dimensional image changes discontinuously or "flips". A problem with this type of display is that the images seen by the viewer are separated by dark regions associated
- 20 with gaps between the projection lenses.

In a paper entitled "Autostereoscopic 3D-imaging by front and rear projection and on flat panel displays" by R Borner which was published in "Displays", Volume 14, Number 1, 1993 by Butterworth-Heinemann

25 Ltd, this problem is tackled by overlapping the exit pupils of the projector lenses by using at least two vertically spaced layers of projectors lenses horizontally off-set with respect to each other. In this way the axis of an exit pupil of a projector lens in a first layer will lie in a horizontal plane located between the axes of the exit pupils of two adjacent projector

30 lenses in a second layer. The images of the projector lens exit pupils from different layers can be overlapped in the "viewer space" using lenticular screens in order to eradicate dark regions between the images

in the "viewer space". A similar approach is used in a paper entitled "An autostereoscopic real-time 3D display system" by G. Bader, E. Lueder and J. Fuhrmann published in Euro Display '96. The resulting display apparatus using such multi-layer arrangements can be overly complex and the use of lenticular arrays to spread out the exit pupil image can affect the projected picture quality.

In a paper entitled "Multiperspective autostereoscopic display" by Gordon R. Little, Steven C. Gustafson and Vasiliki E. Nikolaou published in SPIE Volume 2219 Cockpit Displays (1994), the problem of gaps between adjacent images in the "viewer space" is solved by using a pupil forming screen which comprises a Fresnel lens and a lenticular array to spread out each image in the "viewer space" to remove any gaps between adjacent images. This again has the disadvantage of affecting the projected picture quality by reducing the resolution of the display.

The present invention aims to overcome at least some of the problems discussed above by providing a compound lens arrangement for use in arrays of lenses which substantially eliminates the problem of dark spaces between images in the "viewer space" without requiring over-complex display arrangements and without reducing the resolution of the image seen by the viewer.

According to a first aspect of the present invention there is provided a compound lens arrangement for use in an array of such lens arrangements comprising at least two lens elements including a front lens element having a front lens surface which is the largest diameter lens surface in the compound lens arrangement, wherein the exit pupil of the compound lens arrangement is bounded by and lies in the plane of the edge of said front lens surface. In such a compound lens arrangement the exit pupil lies at the front of the arrangement at the

largest diameter lens surface of the arrangement which means that in an array of such compound lens arrangements, adjacent abutting lens arrangements will have adjacent abutting exit pupils. Thus, there will be no gaps between the exit pupils of adjacent compound lens arrangements and so the present invention can be used to eliminate the problem of dark spaces between images in the "viewer space" in autostereo projection systems. The compound lens arrangement according to the present invention is of use in any application requiring the use of arrays of lenses with abutting exit pupils.

10

The aperture stop may be located within the front lens element of the compound lens. Preferably, the aperture stop of the lens lies in front of the lens element(s) of the compound lens arrangement other than the front lens element as this improves the symmetry of the lens arrangement about the aperture stop and helps to reduce coma, distortion and transverse colour in the compound lens. The aperture stop of the compound lens arrangement may lie in a plane which intersects the optical axis of the compound lens arrangement at the rear lens surface of the front lens element.

20

The front lens element may itself be a compound lens or alternatively could comprise a single lens. It is preferred that the rear lens surface of the front lens element is concave and further that the front lens surface of the front lens element is convex.

25

In a preferred arrangement the front lens element is the largest diameter lens element in the compound lens arrangement.

30

The first aspect of the present invention relates to a compound lens arrangement with its exit pupil located at its last (or front) surface with the edge of the exit pupil being the intersecting ring of the plane where the exit pupil is located and said last surface. The diameter of the exit

pupil defines the largest diameter of the compound lens arrangement and the radius of the exit pupil is larger than or equal to all the ray heights traced through the compound lens without vignetting. Thus, several such compound lenses can be arranged in an array so that their exit pupils abut so that there will be no dark zone when this compound lens array is used as the projection lens array in a multi-projector autostereoscopic display.

According to a second aspect of the present invention there is provided a projector for use in an array of such projectors comprising a compound lens arrangement according to the first aspect of the present invention. As discussed above such a projector can be used in an abutting array of such projectors in an autostereo projection system in order to eliminate gaps between images in the "viewing space" of the system.

According to a third aspect of the present invention there is provided an autostereo projection system comprising an array of projectors according to the second aspect of the present invention.

According to a fourth aspect of the present invention there is provided a method of designing a compound lens arrangement for use in an array of such lenses comprising the steps of,

defining the material of a front lens element of the compound lens arrangement, the diameter of a front lens surface of the front lens element, the radius of curvature of the front lens surface and a rear lens surface of the front lens element and defining the location of an exit pupil of the compound lens arrangement to be bounded by and in the plane of the edge of said front lens surface,

based on the above defined parameters, tracing the location and magnitude of an aperture stop of the compound lens arrangement by tracing the marginal rays through the front lens element using ray tracing means,

5

repeating the above steps until the marginal ray heights through the front lens element are highest at the exit pupil, and then fixing the above defined parameters,

10

defining the diameters of the remaining lens surfaces of the compound lens arrangement to be less than that of the front lens surface of the front lens element and defining the functionality of the compound lens arrangement,

15

using ray tracing means to design the remainder of the compound lens arrangement, in such a way that the remaining lens surfaces do not alter the relationship between the exit pupil and the marginal ray height through the front lens element defined above.

20

Preferably, the parameters defined in the first step of the method are only fixed when the diameter of the aperture stop is less than the diameter of the exit pupil.

25

This method can be used to design a compound lens arrangement according to the first aspect of the present invention and which will have the advantages associated with the first aspect of the present invention.

30

The term marginal ray is used generally to describe those rays which pass through the edge of an aperture stop or an entrance or exit pupil of a lens system. The marginal ray is that ray which is the highest (ie. moves furthest away from the optical axis) amongst the rays traced

through a lens system from an object point. In a compound lens according to the present invention the marginal rays will pass through the edge of the exit pupil, because the exit pupil is real.

- 5 Preferably, the step of defining the diameter of the front lens surface of the front lens element comprises the step of defining the diameter of the front lens element.

10 Preferably, the step of defining the functionality of the compound lens arrangement comprises the step of defining the compound lens as a finite conjugate lens with specified object and image distances as such a compound lens would be suitable for use in a projector of an autostereo projection system. Alternatively, the compound lens arrangement could be defined as a finite-infinite conjugate lens element.

15 For the purposes of the present invention the aperture stop shall be defined as the image of the exit pupil.

20 The present invention will now be described by way of example only with reference to the accompanying figures in which:

Figure 1a shows schematically a multi-perspective autostereo display system using a direction selective projection screen and an array of projectors each comprising a compound lens according to the present invention.

Figure 1b shows schematically a multi-perspective autostereo display system using a field lens and an array projectors each comprising a compound lens according to the present invention.

30 Figure 2 shows a first embodiment of a compound lens arrangement according to the present invention.

element (32) with the aperture stop, which is a virtual image of the exit pupil lying in the plane (40). In the absence of the front lens element (32) the marginal rays from all three field points (44,48,50) would intersect at point (52) as shown by the ray construction in dotted lines.

- 5 Point (52) defines the upper edge of the of the aperture stop of the compound lens (30) of Figure 2. The addition of the front lens element (32) refracts the marginal rays at its rear surface (b) so that they intersect at point (54) which is the upper edge of the exit pupil of the compound lens (46). The exit pupil is the image of the aperture stop at
10 the image side of the aperture stop, and so lies in a plane (46) perpendicular to the optical axis (42) and is bounded by intersection points (54). The front lens element (32) is designed so that the intersection points (54) lie at the circumference of the front surface (a) of the front lens element (32). The compound lens (30) is designed so that
15 the circumference of the front surface (a) of the front lens element (32) is greater than any other circumference of a lens element used in the compound lens. In this way adjacent compound lenses (30) can be placed together in an array with their exit pupils abutting.
- 20 The aperture stop is a virtual image of the exit pupil. The height of the aperture stop is the distance from the point (52) to the optical axis (42) and the height of the marginal ray at the exit pupil is the distance from the point (54) to the optical axis (42). It can be seen that the marginal ray heights all the way through the front lens element (32) are less than
25 the marginal ray height at the exit pupil.

It should be noted that the front lens element (32) could be a compound lens element comprising more than one lens element.

- 30 The compound lens (30) is designed as indicated above using the Code V software package. It is designed in accordance with the following method, the steps of which are shown in Figure 7:

Claims

1. A compound lens arrangement for use in an array of such lens
5 arrangements comprising at least two lens elements including a front
lens element having a front lens surface which is the largest diameter
lens surface in the compound lens arrangement, wherein the exit pupil
of the compound lens arrangement is bounded by and lies in the plane
of the edge of said front lens surface.
10
2. A compound lens arrangement according to claim 1 wherein the
aperture stop of the lens arrangement lies in front of the lens elements
of the compound lens arrangement other than the front lens element.
- 15 3. A compound lens arrangement according to claim 1 wherein the front
lens element has a rear lens surface and the aperture stop of the
compound lens arrangement lies in a plane which intersects the optical
axis of the compound lens arrangement at the rear lens surface.
- 20 4. A compound lens arrangement according to any one of the
preceding claims wherein the front lens element is a compound lens.
5. A compound lens arrangement according to any one of claims 1 to 3
wherein the front lens element is a single lens.
25
6. A compound lens arrangement according to any one of the
preceding claims wherein the front lens element is the largest diameter
lens element in the compound lens arrangement.
- 30 7. A compound lens arrangement according to the present invention
wherein a rear lens surface of the front lens element is concave.

8. A compound lens according to any one of the preceding claims wherein the front lens surface of the front lens element is convex.

9. A projector for use in an array of such projectors comprising a compound lens arrangement according to any one of the preceding claims.

10. An autostereo projection system comprising an array of projectors according to claim 9.

10

11. A method of designing a compound lens arrangement for use in an array of such lenses comprising the steps of;

15

defining the material of a front lens element of the compound lens arrangement, the diameter of a front lens surface of the front lens element, the radius of curvature of a front lens surface and a rear lens surface of the front lens element and defining the location of an exit pupil of the compound lens arrangement to be bounded by and in the plane of the edge of said front lens surface,

20

25

based on the above defined parameters, tracing the location and magnitude of an aperture stop of the compound lens arrangement by tracing the marginal ray height through the front lens element using ray tracing means,

30

repeating the above steps until the marginal ray height traced through the front lens element is highest at the exit pupil and then fixing the above defined parameters,

defining the diameters of the remaining lens surfaces of the compound lens arrangement to be less than that of the front lens surface of the front lens element and defining the functionality of the compound lens arrangement, and

5

using ray tracing means to design the remainder of the compound lens arrangement in such a way that the remaining lens surfaces do not alter the relationship between the exit pupil and the marginal ray height through the front lens element as defined above.

10

12. A method according to claim 11 wherein the parameters defined in the first step of the method are only fixed when the diameter of the aperture stop is less than the diameter of the exit pupil.

15

13. A method according to claim 11 or 12 wherein the step of defining the diameter of the front lens surface of the front lens element comprises the step of defining the diameter of the front lens element.

20 14. A method according to any one of claims 11 to 13 wherein the step of defining the functionality of the compound lens arrangement comprises the step of defining the compound lens arrangement as a finite conjugate lens with specified object and image distances.

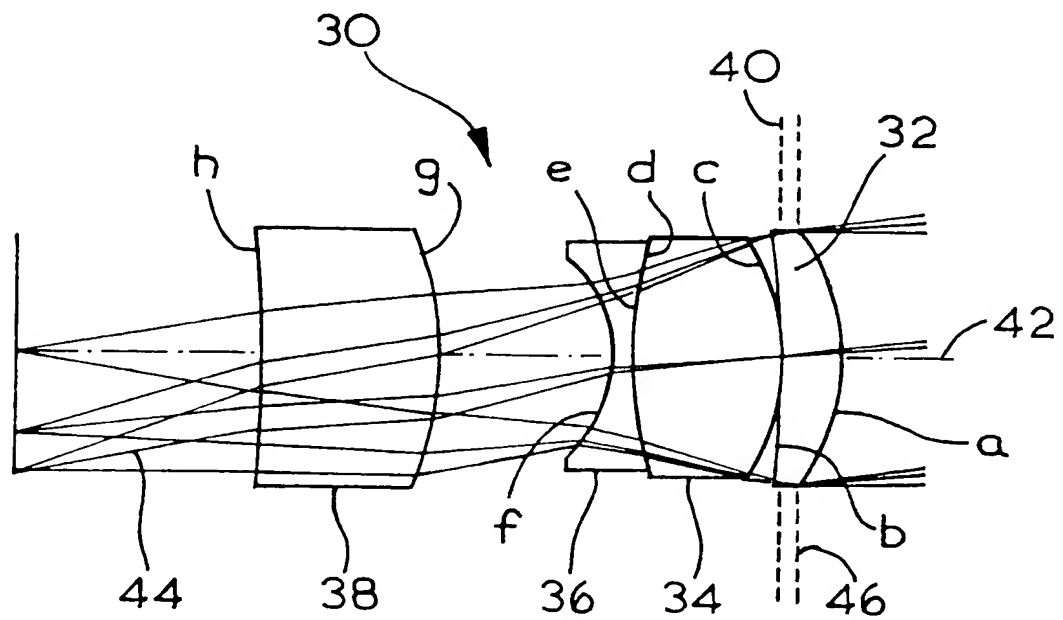


FIG. 2

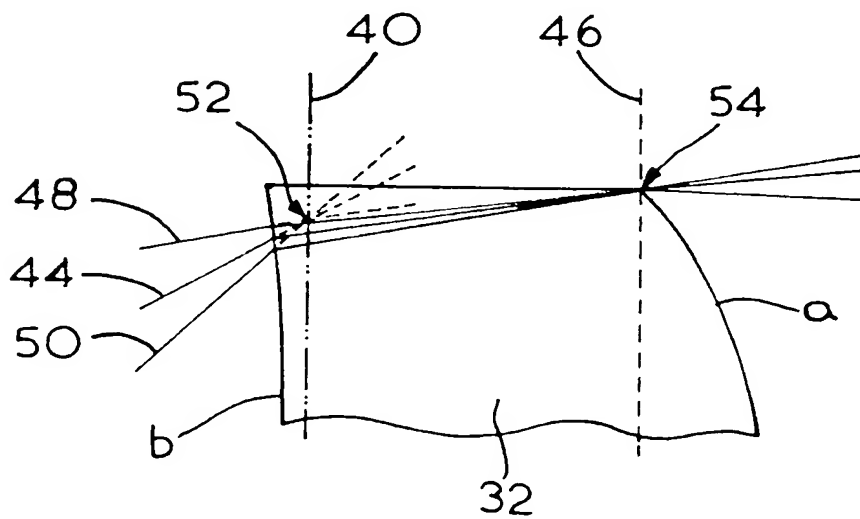


FIG. 4

PATENT COOPERATION TREATY

from the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

Commissioner
 US Department of Commerce
 United States Patent and Trademark
 Office, PCT
 2011 South Clark Place Room
 CP2 5C24
 Arlington, VA 22202
 ETATS UNIS D'AMERIQUE

Date of mailing (day, month, year) 03 April 2001 (03.04.01)	
International application No. PCT GB00 02736	Applicant's or agent's file reference P60049WO
International filing date (day, month, year) 17 July 2000 (17.07.00)	Priority date (day, month, year) 19 July 1999 (19.07.99)
Applicant CHEN, Cheng-Huan	

1. The designated Office is hereby notified of its election made:



in the demand filed with the International Preliminary Examining Authority on

15 February 2001 (15.02.01)



in a notice effecting a later election filed with the International Bureau on

2. The elector ☒ was:

was not

Respectfully the elector is notified that the priority date of the international application with the filing date of the
 Request is:

The International Bureau of WIPO
 41, chemin des Colombettes,
 1211 Geneva 20, Switzerland

PATENT COOPERATION TREATY

PCT

NOTIFICATION OF THE RECORDING
OF A CHANGE(PCT Rule 92bis 1 and
Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

BOWDERY, A. O.
Qinetiq Limited
IP Formalities
A4 Bldg, Cody Technology Park
Ively Road, Farnborough
Hampshire GU14 0LX
ROYAUME UNI

Date of mailing (day, month, year) 05 November 2001 (05.11.01)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference P60049WO	
International application No. PCT GB00 02736	
International filing date (day, month, year) 17 July 2000 (17.07.00)	

1. The following indications appeared on record concerning

☒ the applicant ☐ the inventor ☐ the agent ☐ the common representative

Name and Address THE SECRETARY OF STATE FOR DEFENCE Defence Evaluation and Research Agency Ively Road Farnborough Hampshire GU14 0XL United Kingdom	State of Nationality GB	State of Residence GB
	Telephone No.	
	Facsimile No.	
	Telex No.	

2. The International Bureau hereby notifies the applicant that the following indications appeared on record

☒ the person ☐ the name ☐ the address ☐ the nationality ☐ the residence

Name and Address QINETIQ LIMITED 25 Buckingham Gate London SW1 6TD United Kingdom	State of Nationality GB	State of Residence GB
	Telephone No.	
	Facsimile No.	
	Telex No.	

3. The following indications appeared on record

4. A declaration is made by the applicant that the following indications are correct	
<input checked="" type="checkbox"/> The applicant is the inventor of the invention.	<input type="checkbox"/> The applicant is not the inventor of the invention.
<input type="checkbox"/> The applicant is not the inventor of the invention.	<input checked="" type="checkbox"/> The applicant is the inventor of the invention.
<input type="checkbox"/> The applicant is not the inventor of the invention.	<input type="checkbox"/> The applicant is the inventor of the invention.

The International Bureau of WIPO
84, Chemin de la Corniche
1211 Geneva 20, Switzerland

Date of mailing



The Secretary of State for Defence
% Harrison Goddard Foote
1 Stockport Road
Marple
STOCKPORT
SK6 6BD

27 DEC 1999

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

Examiner: 01633 814799
E-mail: chris.ross@patent.gov.uk
Switchboard: 01633 814000
Fax: 01633 814444

Your Reference: HR/P60049GB
Application No: GB 9916715.7

3 December 1999

Dear Sirs

Patents Act 1977: Search Report under Section 17(5)

I enclose two copies of my search report and a copy of the citations. Claims 14 -18 have not been searched since they do not appear to be directed to patentable subject matter and appear to be excluded under Section 1(2). If these claims are retained, this point will be considered further at substantive examination on filing of F10/77.

Publication

I estimate that, provided you have met all formal requirements, preparations for publication of your application will be completed soon after **12 December 2000**. You will then receive a letter informing you of completion and telling you the publication number and date of publication.

Amendment/withdrawal

If you wish to file amended claims for inclusion with the published application, or to withdraw the application to prevent publication, you must do so before the preparations for publication are completed. **No reminder will be issued.** If you write to the Office less than 3 weeks before the above completion date, please mark your letter prominently: **"URGENT - PUBLICATION IMMINENT"**.



Application No: GB 9916715 7

Page 2

3 December 1999

Yours faithfully

Chris Ross
Examiner



Application No: GB 9916715.7
Claims searched: 1-13

Examiner: Chris Ross
Date of search: 2 December 1999

Patents Act 1977 Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): G2J(JB7C14, JB7P, JX15, JB7CX)

Int Cl (Ed.6): G02B

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2296783 A (SAB) Figs 1, 6	at least
"	GB 1502546 A (RANK) Fig 2	"
"	GB 1215842 A (CEA) the Fig	"
"	US 5835288 A (FPO) col 2 l 48 on	"
A	US 4852980 A (DSMC) Fig 26, col 11 l 49 on	

- i Document indicating lack of inventive step
ii Document indicating lack of inventive step combined with one or more other documents of same category
iii Member of the same patent family

- iv Document indicating technical problem to be solved
v Document published on or after the date of priority but before the date of the invention
vi Patent document published on or after the date of priority but before the date of the application

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY:

PCT

NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL SEARCH REPORT
OR THE DECLARATION

(PCT Rule 44.1)

To:
Harrison Foote Goddard
1 Stockport Road
Attn: REGAN, Heather
Marple
Stockport SK6 6BD
UNITED KINGDOM

11 DEC 2000 7 530

Date of mailing (day month year)	07/12/2000
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Applicant's or agent's file reference P60049W0	FOR FURTHER ACTION See paragraphs 1 and 4 below
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International application No. PCT/GB 00/02736	International filing date (day month year) 17/07/2000
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Applicant THE SECRETARY OF STATE FOR DEFENCE
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1. ☒ The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.
- Filing of amendments and statement under Article 19:**
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46.).
- When?** The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.
- Where?** Directly to the International Bureau of WIPO
84, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35
- For more detailed instructions,** see the notes on the accompanying sheet.
2. ☐ The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.
3. ☐ **With regard to the protest** against payment of (any) additional fees, under Rule 40(2), the applicant is notified that:
- ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices;
 - ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.
4. **Further action(s):** The applicant is reminded of the following:
- Shortly after **18 months** from the priority date, the International Application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the International Application, or of the priority claim, must reach the International Bureau as provided in Rules 90bis.1 and 90bis.3, respectively, before the completion of the technical preparations for international publication.
 - Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date, in some Offices even later.
 - Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before a designated Office which has not been elected in the demand or in a later election within 19 months from the priority date or should not be elected because they are not covered by Chapter I.

Name and mailing address of the International Searching Authority: European Patent Office, P.O. Box 5910, Patentlaan 1 NL-1220 ES, Rijswijk Tel.: +31-70 340-2140, Fax: +31-70 340-2141 E-mail: +31-70 340-2142	Authorized official: Marie-Françoise Provost
---	---

These Notes are intended to give the basic instructions concerning the filing of amendments under Article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When?

Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How?

Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped), whether

- (i) the claim is unchanged,
- (ii) the claim is cancelled,
- (iii) the claim is new,
- (iv) the claim replaces one or more claims as filed,
- (v) the claim is the result of the division of a claim as filed

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

- 1 [Where originally there were 48 claims and after amendment of some claims there are 51]
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."
- 2 [Where originally there were 15 claims and after amendment of all claims there are 11]
"Claims 1 to 15 replaced by amended claims 1 to 11."
- 3 [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."
- 4 [Where various kinds of amendments are made]
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international application is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must, preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 52.2(a), first sentence).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference P60049W0	FOR FURTHER ACTION see Notification of Transmittal of International Search Report Form PCT/ISA/220, as well as, where applicable, item 5 below.	
International application No. PCT/GB 00/02736	International filing date (day month year) 17/07/2000	Earliest Priority Date (day month year) 19/07/1999
Applicant THE SECRETARY OF STATE FOR DEFENCE		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of **4** sheets.
☒ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing:

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (see Box III).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established according to Rule 36.1(b) by this Authority as it appears in Box I. The applicant may, within one month from the date of mailing of this International Search Report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No.

☒ as suggested by the applicant.

☐ because the applicant failed to supply a figure.

☐ because this figure better illustrates the invention.

1a

☐ None of the figures.

PC 00/02736

IPC 7 G02B27/22 H04N13/00

A π -stable π -homomorphism $\phi: A \rightarrow B$ is called *stable* if $\phi|_{\pi(A)} = 0$.

Additional information is available in the following table:

IPC 7 G02B H04N

For a complete list of songs, see the list of songs in the appendix. The songs are listed in the order in which they were performed.

base from data base 1, considered during the international search, in terms of data base 2 and 3, where plural seat numbers are used.

WPI Data. EPO-Internal. PAJ. INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Applying (1) to (2) and (3) and using (4) and (5) we obtain

Experiments were performed in a 1000-ml glass bottle.

X WO 98 43441 A (MCLAUGHLIN JOSEPH L :MARTIN
GRAHAM (US): LITTON SYSTEMS INC (US))
1 October 1998 (1998-10-01)
page 3. line 12 - line 19
page 6. line 11 - line 19
A figure 2

1,2,5,6

A

3.4.7-14

P.X | CHEN C H ET AL: "New projection lens for
| three-dimensional displays "
| ELECTRONICS LETTERS..
| vol. 35. no. 24.
| 25 November 1999 (1999-11-25). pages
| 2137-2138. XP000961582
| IEE STEVENAGE.. GB
| ISSN: 0013-5194
| the whole document

1-14

[illegible][illegible]

56. $\frac{1}{2} \left(\frac{1}{2} + \frac{1}{2} \right) = \frac{1}{2}$

*We have also performed the following studies: (1) the effect of W^+ on the rate of skeletal growth; (2) the effect of W^+ on the rate of bone growth; (3) the effect of W^+ on the rate of bone growth in the presence of W^- .

* The right to life, liberty and pursuit of happiness is the state's duty to protect.

* The number of W and W bonds is equal, but S and W bonds are not equal. The number of S bonds is $2N$ and the number of W bonds is $2N - 2$.

[illegible]

* *Journal of the American Medical Association*, 1990; 263: 1033-1035.

1997). The results of the study suggest that the effect of the type of the stimulus on the response is not significant. With the use of the proposed model, the results of the proposed model are compared with the results of the proposed model.

N The following is a list of the names of the persons who have been appointed to the various committees of the Board of Directors of the American Association of University Professors, for the year 1934-1935. The names are given in alphabetical order of the last name of the person.

[illegible]

• **Prevalence:** 10% of the population in the United States has a chronic mental health condition.

1. *Journal of the American Medical Association*, 1997; 277: 1039-1043.

1. *Phragmites australis* (Rostk & Schmidt) Bosc.

20 November 2000

07/12/2000

* *Chlorophyll a* and *Chlorophyll b* were determined by the method of Arar and Collins (1987). The *Chlorophyll a* and *Chlorophyll b* contents were determined by the method of Arar and Collins (1987). The *Chlorophyll a* and *Chlorophyll b* contents were determined by the method of Arar and Collins (1987).

Ward, S.

INTERNATIONAL SEARCH REPORT

International Application No

PCT 00/02736

C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Reference to the document, with indication whether applicable to the whole document or to a part thereof	Relevant part
A	US 4 756 601 A (SCHROEDER WOLFGANG) 12 July 1988 (1988-07-12) abstract: figures ---	1-10
A	US 5 614 941 A (HINES STEPHEN P) 25 March 1997 (1997-03-25) abstract: figures ---	1-10
A	US 5 825 540 A (GOLD RONALD S ET AL) 20 October 1998 (1998-10-20) abstract: figures ---	1-10
A	PATENT ABSTRACTS OF JAPAN vol. 1997, no. 01. 31 January 1997 (1997-01-31) & JP 03 240788 A (CANON INC). 17 September 1996 (1996-09-17) abstract: figures ---	1-10
A	EP 0 535 651 A (US PRECISION LENS INC) 9 March 1994 (1994-03-09) abstract: figures ---	11
A	US 5 568 322 A (AZAMI KAE ET AL) 22 October 1996 (1996-10-22) figure 4 ---	1.11
A	US 4 109 263 A (JOHNSON BRUCE K) 22 August 1978 (1978-08-22) column 5, line 26 - line 31 ---	1.11
A	BADER G ET AL: "8 1: AN AUTOSTEREOSCOPIC REAL-TIME 3D DISPLAY SYSTEM" EURODISPLAY, SID'S INTERNATIONAL DISPLAY RESEARCH CONFERENCE. vol. CONF 16. 1 October 1996 (1996-10-01), pages 101-104, XP000729551 ISSN: 1033-1312 cited in the application the whole document ---	1.11
A	BÖRNER R: "Autostereoscopic 3D-Imaging by Front and Rear Projection and on Flat Panel Displays" DISPLAYS. vol. 14, no. 1, 1993, pages 39-46. XP000960395 Butterworth-Heinemann Ltd. GB ISSN: 0141-9382 cited in the application the whole document ---	1.11

INTERNATIONAL SEARCH REPORT

International Application No

PC 00/02736

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

No.	Relevant Document with Indication Where Relevant Part of the Document is Cited	Relevant Part
A	LITTLE G R ET AL: "Multiperspective autostereoscopic display " PROCEEDINGS OF THE SPIE . vol. 2219. 7 - 8 April 1994. pages 388-394. XP000961626 Orlando, FL, USA cited in the application the whole document	1.11
A	BORN MAX AND WOLF EMIL: "PRINCIPLES OF OPTICS" 1974 . PERGAMON PRESS. (5TH EDITION) XP002152171 page 186	1-14

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT 00/02736

Patent document cited in search report		Publication date	Patent family members	Publication date
WO 9843441	A	01-10-1998	US 5993003 A AU 8937998 A EP 0970589 A	30-11-1999 20-10-1998 12-01-2000
US 4756601	A	12-07-1988	DE 3441745 A EP 0181638 A	22-05-1986 21-05-1986
US 5614941	A	25-03-1997	US 5430474 A	04-07-1995
US 5825540	A	20-10-1998	BE 1011677 A GB 2312528 A.B JP 10039783 A NL 1005858 C NL 1005858 A	07-12-1999 29-10-1997 13-02-1998 27-07-1999 23-10-1997
JP 08240788	A	17-09-1996	NONE	
EP 0585651	A	09-03-1994	US 5313330 A DE 69328891 D DE 69328891 T EP 0974859 A JP 6160714 A	17-05-1994 27-07-2000 26-10-2000 26-01-2000 07-06-1994
US 5568322	A	22-10-1996	JP 7005354 A	10-01-1995
US 4109263	A	22-08-1978	AT 368301 B AT 538877 A CA 1088795 A CH 618796 A DE 2738826 A FR 2363811 A GB 1586537 A JP 1344444 C JP 53041222 A JP 61003415 B	11-10-1982 15-01-1982 04-11-1980 15-08-1980 16-03-1978 31-03-1978 18-03-1981 29-10-1986 14-04-1978 01-02-1986

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
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PCT

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(GB).

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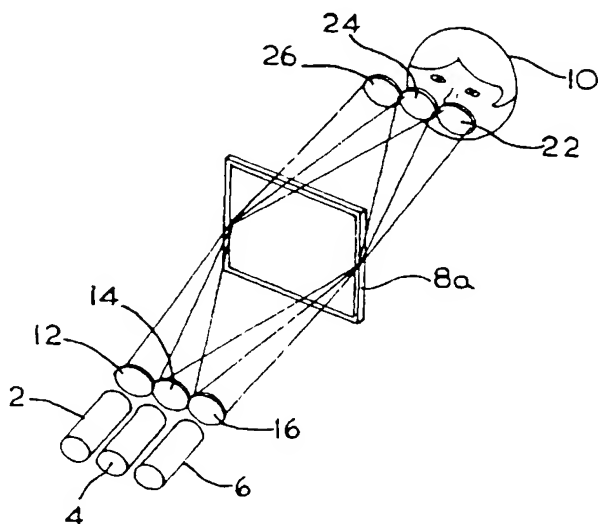
Published:

With international search report.

Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette

(54) Title: COMPOUND LENS ARRANGEMENT FOR USE IN LENS ARRAYS



(57) Abstract: A compound lens arrangement for use in an array of such lens arrangements comprising at least two lens elements including a front lens element having a front lens surface which is the largest diameter lens surface in the compound lens arrangement, wherein the exit pupil of the compound lens is bounded by and lies in the plane of the edge of said front lens surface. This enables the compound lens arrangements in an array to abut. The invention particularly relates to compound lens arrangements for use in projectors which projectors are used in an array in an autostereo projection system and allows adjacent projectors to abut.

WO 01/06299 A1

To realize flicker-free scenes, it is necessary that the full set of twenty views be presented within 1/50 seconds. The DMD is unique among currently available spatial light modulators in providing this high frame rate (1000 gray-scale frames per second). A considerable portion of the cost to develop a DMD-based system is associated with the digital electronics needed to format imagery and transfer it to the DMD at this rate. Note that since the display has no persistence, high speed electronics are required even if only static scenes are displayed.

2.2 Space-multiplexed implementation

A space-multiplexed implementation of our display concept featuring video cameras and liquid crystal television (LCTV) projectors is depicted in Figure 2. Here, the array of video cameras captures multiple perspective views of a real scene. These views are fed directly to the array of LCTVs and simultaneously projected onto a special pupil-forming viewing screen. The viewing screen permits each perspective view to be seen only at the appropriate viewer position. The screen could be fabricated as a holographic optical element, but it can also be realized using a Fresnel lens and a pair of crossed lenticular arrays. In this case, the angular separation of the exit pupils is equal to the angular separation of the projection channels, and the viewing zone angular width is determined by the angular subtense of the projector array. Note that fixed transparencies can replace the LCTVs, enabling higher resolution imagery to be displayed.

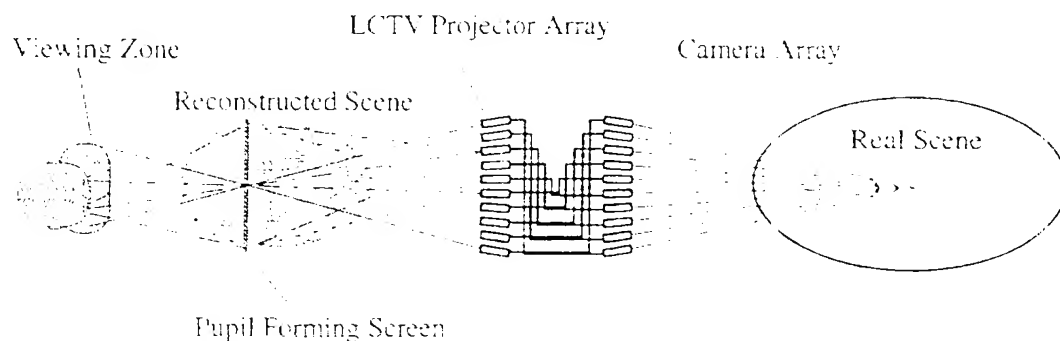


Figure 2. Space-multiplexed implementation of multiperspective autostereoscopic display.

3. DESIGN ISSUES FOR A SPACE-MULTIPLIED DISPLAY

Development of an effective space-multiplexed implementation of our display concept requires consideration of the two critical subsystems: the pupil-forming screen and the projection optics. Important design issues for these subsystems are discussed below.

3.1 Pupil-forming screen

Operation of the Fresnel lens lenticular array pupil-forming screen is explained in the top views of Figure 3. Figure 3a shows a rear projection system using a simple diffusing screen in which light from each part of the projected image is scattered over large angles, enabling the viewer to see the image over a wide region. The diffuser is replaced by a Fresnel lens in Figure 3b, with the result that the image can only be seen at a single-point exit pupil in the viewing plane (here, at the viewer's left eye position).

A lenticular array having its cylindrical lenslet axis vertical is added in Figure 3c, causing the pupil to be spread horizontally. Finally, Figure 3d illustrates the same screen with three projectors. The screen forms a separate exit pupil for each of the projectors, enabling the viewer to see different images with each eye. By adding a second lenticular array having its axis horizontal, the exit pupils are spread vertically, providing a comfortable range of viewing heights.

The height and width of the exit pupils are determined by the f-numbers of the cylindrical lenslets in the two lenticular arrays. A standard $f/4$ lenticular array yields an exit pupil height of seven inches at a viewing distance of 28 inches. A custom array with $f/56$ is needed to achieve an exit pupil width of 0.5 inch (corresponding to an exit pupil separation of one degree) at this viewing distance. Exit pupils of this size would permit seven inches of viewer height adjustment and would provide a horizontal viewing zone for 3D scenes (both eyes receiving images) of about 7.5 inches. Some flexibility in lenticular array f-number can be achieved by using index-matching materials to alter lenslet focal lengths.³

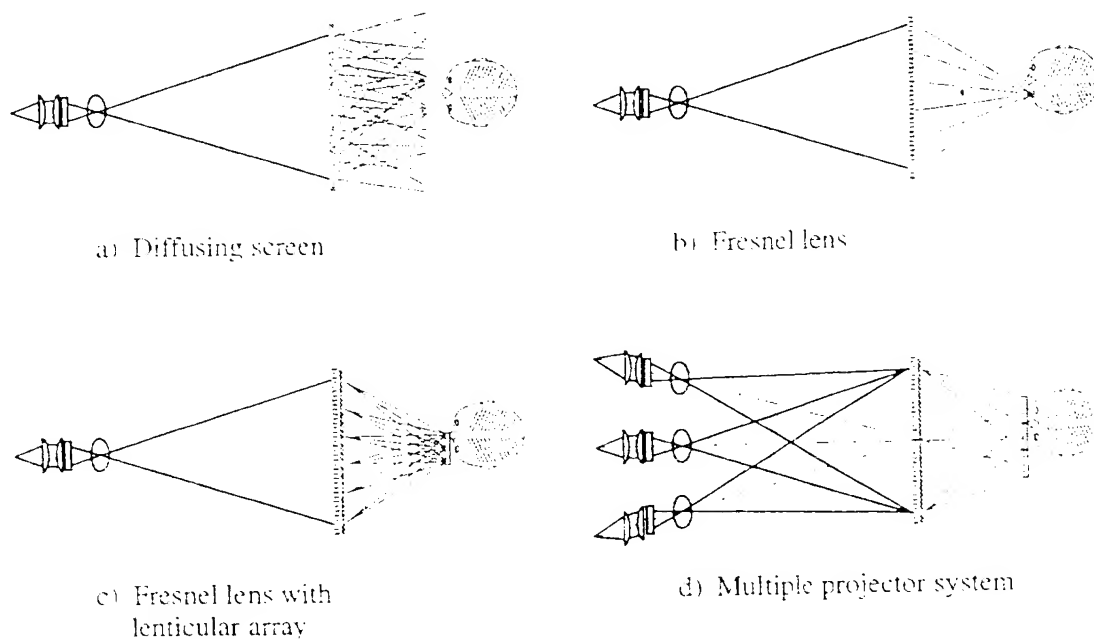


Figure 3. Operation of a pupil-forming screen consisting of a Fresnel lens and a lenticular array: a) diffusing screen; b) Fresnel lens; c) Fresnel lens with lenticular array; d) multiple projectors.

The viewing depth range over which sharp 3D images can be seen is proportional to the ratio of the viewing range to the screen width. For a 400 mm (16") screen width, a range of about one inch is anticipated. Larger viewing depth ranges could be achieved by using smaller screens. In any event, the degradation with viewer depth position is expected to be gradual, which is not the case in parallax barrier approaches.

Lenticular arrays limit the resolution of the display because the image segment that impinges on

any lenslet is distributed across the entire exit pupil. For a typical array pitch (two lenses per millimeter) used with a 400 mm (H) by 300 mm (V) (16" by 12") viewing screen, resolution can be no better than 600x800. Displays with smaller viewing screens but the same array pitch will have correspondingly fewer pixels. Note that increasing the pitch is undesirable due to diffraction blurring of the exit pupil edges.³ Using an HOE as the pupil-former should eliminate these restrictions.

Our application of lenticular arrays differs from that commonly encountered in novelty autostereoscopic displays. In these novelty devices, right and left eye images are combined in strip form with one right and one left strip precisely positioned under each lenslet at the lenslet focal plane.⁴ In this case, each eye sees only the appropriate set of strips and a stereoscopic image is observed. This novelty application requires careful alignment between the image strips and the array and good control on array thickness. In our application, both of these restrictions are substantially relaxed; we are using the arrays as controlled diffusers, not as image formers.

An important feature of our design is that the pupil-forming function is separated from the image-forming function. Using the Fresnel lens off-axis, for example, introduces only minor degradation in the exit pupils and does not directly impact the image. Acceptable pupils have been demonstrated over a viewing angular range of 20 degrees.³

3.2 Projection optics

The projection optics subsystem includes multiple channels that are essentially identical, each having a light source (lamp and condenser lens), an image source, and a projection lens. As depicted in Figure 4, the system features specular (rather than diffuse) illumination with the lamp source imaged by the condenser onto the projection lens. The image source (LCTV or film transparency) is placed just behind the condenser and is imaged onto the pupil-forming screen. Each of these components is discussed below.

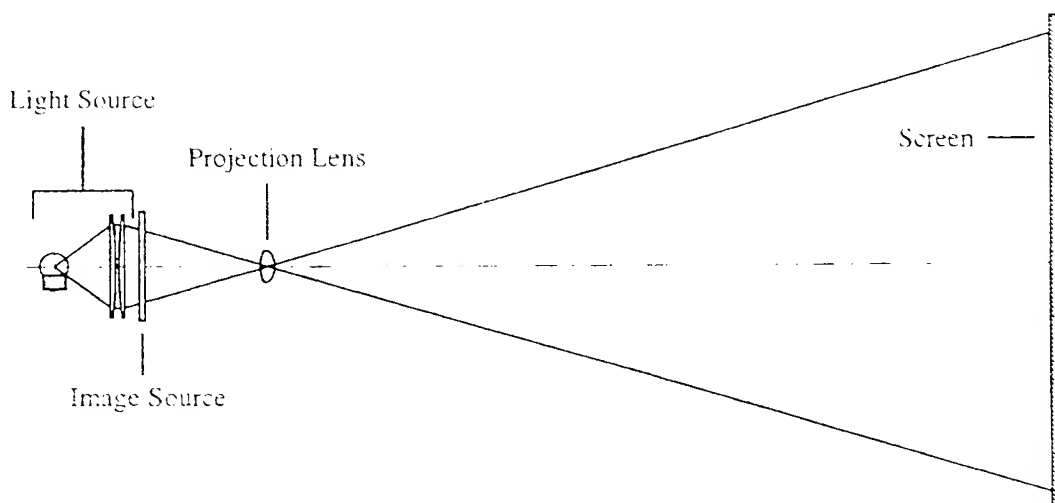


Figure 4. Schematic of single projection channel.

The light source for each channel includes a small filament tungsten lamp and a condenser lens. Since all of the light collected by the condenser (apart from absorption and reflection losses) ends up in the exit pupil, lamp luminous output can be quite small, even for viewing under high ambient illumination levels. In particular, the composite luminous flux for all channels is no more than that required for a single-channel, rear-projection display using a diffusing screen of the same size. The low single-channel luminous flux means that inexpensive, lightweight and thin Fresnel condenser lenses may be used.

The space-multiplexed 3D display implementation illustrated in Figure 2 used LCTVs as the image source. Such a system is capable of displaying dynamic, full-color scenes with resolution limited by the LCTVs. Currently available liquid crystal display (LCD) modules suitable for use in the system include miniature LCTVs and color LCD monitors recently introduced in camcorders. A critical requirement for our application is small size, principally because the 20 projection channels must have an angular separation matching that of the exit pupils (one degree). A secondary requirement is high resolution so that the projected images are sharp. While research LCD modules having both small size and high resolution have been reported by Citizen Watch, Ltd.⁵ and Kopin, these are not yet available on the open market. The best compromise currently available at low cost is the miniature color LCD monitor used in camcorders. A unit manufactured by Citizen Watch, Ltd., features 648 (H) by 220 (V) pixels in a 14.6 mm by 10.3 mm format and accepts NTSC video input. These units can be extracted from camcorders or may be purchased separately along with electronic drive modules. By taking advantage of low-cost consumer electronics, considerable cost savings can be realized.

The perspective views can also be provided by fixed transparencies that enable higher resolution and permit use of computer-generated imagery for human factors research. Fixed transparencies for the display can be derived from still photography, motion picture film, video, or computer-generated graphics. With careful design, the same projection and pupil-forming subsystems will be compatible for both image sources.

Projection lenses for a display using the Fresnel lens-lenticular array pupil-former must be small to ensure a reasonable system size, primarily because the angular separation of the projection channels must equal the angular separation of the exit pupils. For a one-degree pupil separation, a 25-mm projection lens diameter implies a lens-screen optical separation of 1.5 m. This separation can be accommodated in a reasonable package by using folding mirrors. Performance requirements for the projection lenses are substantially relaxed over those for many other projection systems. Specular illumination, for example, allows relatively large f-numbers while the resolution limit imposed by the lenticular arrays (discussed earlier) eases MTF requirements. Relatively inexpensive Hastings triplets are expected to provide adequate performance.

In single-channel, rear-projection displays, the projection axis is usually parallel to the viewing screen normal (as in Figure 4). However, most projection channels in our display will be offset (as suggested in Figure 3d). To ensure that all projected images are in focus on the screen and that distortion is minimized, our design calls for orienting the normals to the image sources as well as the axes of the projection lenses all parallel to the screen normal, as in Figure 3d. This scheme satisfies the Scheimpflug condition but requires that the projection lenses be used off-axis. The extreme angle will be ten degrees for a twenty-degree viewing zone.

4. DISCUSSION

Alternative techniques for displaying static or limited-motion 3D scenes having look-around capabilities include the multiplex holograms of Steven Benton and Lloyd Cross and the Holodisk of CFC Applied Holographics, Inc. These techniques, however, integrate the pupil forming and image storage functions and are not suitable for the display of real-time scenes. The separation of these functions in the University's display concept is the enabling feature of our display. Even the University's static (film transparency) scheme readily permits the incorporation of new scenes simply by replacing the transparencies. An entirely new multiplex hologram would have to be generated for each new scene if these other techniques were used.

The laboratory demonstration display described in this paper is intended to lead to the development of a DMD-based autostereoscopic 3D display suitable for cockpit application by enabling demonstration of the advantages of full horizontal parallax. It is anticipated that three stages of development will be required to reach the final goal, with the first stage being the fabrication of the laboratory display. The second stage will consist of human factors experiments to be accomplished using the display. The final stage will involve construction of the DMD-based system. This measured approach is low-risk and cost-effective, and it will permit important assessments of the value of 3D in cockpit applications.

The development of a 3D display technology that is simultaneously autostereoscopic, multiperspective, raster-filled, and dynamic may have substantial impact in areas other than military aviation. These areas may include commercial aviation (cockpits and in air traffic control), robotics (operator controlled remote manipulators), manufacturing, entertainment, and advertising. The development thus has strong potential for implementing the technology transfer goals being advanced by the government.

5. REFERENCES

1. S. C. Gustafson, G. R. Little, T. P. Staub, J. S. Loomis, J. M. Brown and N. F. O'Brien, "Design of a real-time, unskeletonized autostereoscopic display system enabled by new technology," Systems-Oriented Optical Design, SPIE Proceedings Volume 1970, pp 150-159 (1993).
2. J. M. Younse, "Mirrors on a chip," IEEE Spectrum, Volume 30, Number 11, pp 27-31 (1993).
3. L. Locker, Design and performance evaluation of a real-time autostereoscopic display, M.S. Thesis, University of Dayton, Dayton, Ohio, April 1991.
4. T. Okoshi, Three Dimensional Imaging Techniques, Academic Press, New York, 1976.
5. N. Hashimoto, K. Kitamura and S. Morokawa, Practical Holography V, SPIE Proceedings Volume 1461, pp 291-302 (1991).